Scintillation coincidence studies of the delay of Hf181 and Os193 and the isomerism in odd proton nuclei.

de Waard, Hendrik

SUMMARY

This thesis chiefly deals with:
a) the scarcity of long lived odd proton isomers ($\tau_\gamma > 0.1$ sec) in the region $58<Z<82$, hitherto believed to be in contradiction with shell theory,
b) the decay of Hf^{181} ($Z=72$) and Os^{193} ($Z=76$), studied with scintillation coincidence arrangements, the performance of which is analyzed and
c) the measurement of extremely short time intervals with the aid of a pulse-pair generator of special design.

These three seemingly heterogeneous subjects are closely related. For an investigation into the causes of *a* one needs complete data of the excited states of nuclei in the region referred to under *a*. The examination of the radioactive decay of the isotopes mentioned under *b* forms a start for a systematic study of the level schemes of such nuclei. The determination of the lifetimes of isomeric states deserves special attention because more information about the character of these states can be obtained when also the lifetimes have been measured than when, for instance, only the conversion data are known. Such isomeric states, of very short half life, had been found in the decay of the investigated nuclei. For the measurement of such short half lives scintillation counters must be used in a delayed coincidence arrangement, which has been tested and calibrated with the pulse-pair generator mentioned under *c*.

The general part of this thesis, contained in Chapter 1, begins with a summary of the methods by which spin and parity can be assigned to excited states of nuclei (1.1), followed by a survey of the theories of the radiative lifetime of such states (1.2). In section 1.3 empirical curves of $L/(M+N)$ conversion ratio versus Z^2/E_γ (E_γ = γ-energy) are given for magnetic dipole, electric quadrupole and electric octupole radiations. These curves allow a certain decision between magnetic and electric character when the $L/(M+N)$ conversion ratio of a transition has been measured.

An attempt at explaining *a* is made in section 1.4. It is claimed that the prevalence of $g_{7/2}$ low excited or ground states in the greater part of the region $58<\text{odd-}Z<82$ destroys the long lived isomerism expected there from the coexistence of states with high spin ($h_{11/2}$) and low spin ($d_{3/2}$ and $d_{5/2}$). Theoretical

support can be given for the competition of $g_{7/2}$ states with $d_{5/2}$ states in that region. The explanation of the scarcity of long lived odd-Z isomers has been given without abandoning the independent particle model of the nucleus.

It is further demonstrated in section 1.5 that the short lived isomers observed in the same region following β-decay do not involve $h_{11/2}$ levels. In view of arguments given for the non-observability of these levels in β-decay, this is not surprising.

In Chapter 2, section 2, the performance of high resolution scintillation coincidence arrangements is calculated in a few simplified theoretical cases. Some of the results of the calculations are compared with the performance of the arrangement used for the study of b. It is observed that the rise-time spread of the photo-multiplier pulses is an important limitation when venetian-blind type multipliers are used.

Section 2.3 is devoted to the description of a pulse-pair generator especially designed for the measurement of the characteristics of coincidence circuits. Cable delays as small as 10^{-10} sec were measured with this instrument. A pulse forming circuit in which a secondary emission valve is used provided pulses with a minimum rise-time of about 3×10^{-9} sec at the output terminals of the pulse-pair generator. The action of this circuit is analyzed.

In Section 2.4 the "half magnetic-half scintillation" coincidence spectrometer, used for the study of the Os^{193}-decay, and its associated electronic circuits are briefly described. Performance figures are given.

Delayed coincidence measurements on Hf^{181} are reported in Chapter 3. A half life of $(1.06\pm0.03)\times10^{-8}$ sec has been determined for the 481 keV isomeric state in the daughter nucleus Ta^{181}. Consistent assignments are proposed for the levels occurring in the decay of that nucleus.

Chapter 4 gives an account of the measurements performed on the 32 hour decay of Os^{193}. Single count and coincidence spectra of this decay have been measured with the coincidence spectrometer. Three new β-components were observed in coincidence with γ-rays. An unambiguous construction of the disintegration scheme and a determination of all β-branching ratios were made possible by these measurements. The multipole character of most transitions can be determined with reasonable certainty from the measured conversion ratios. It is probable that the first excited level, which is isomeric with a half life measured as $(6.2\pm0.3)\times10^{-9}$ sec, is a $g_{7/2}$ single particle state.